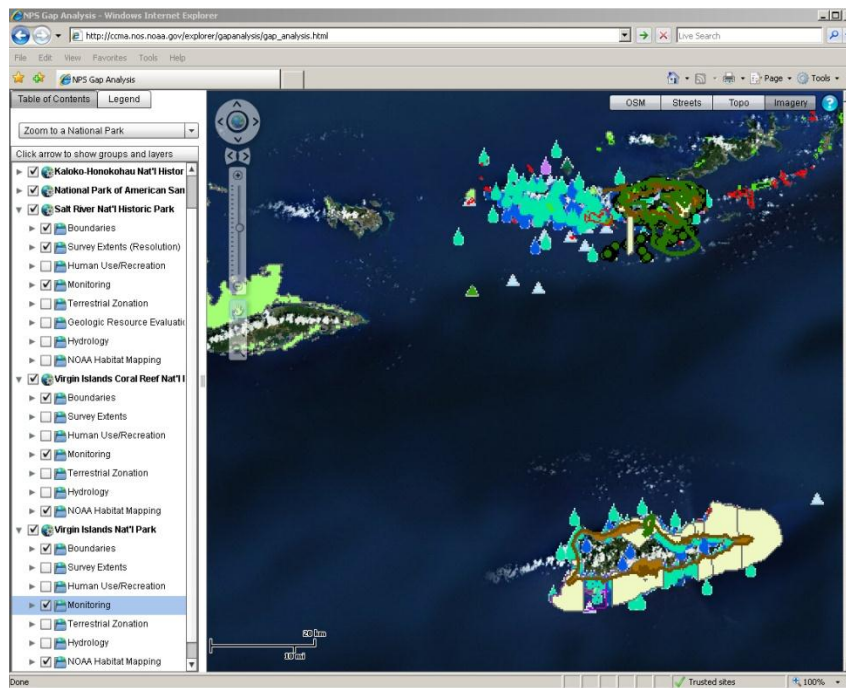


# Gap Analysis of Marine Ecosystem Data



Geospatial Web Portal: [http://ccma.nos.noaa.gov/explorer/gapanalysis/gap\\_analysis.html](http://ccma.nos.noaa.gov/explorer/gapanalysis/gap_analysis.html)

**Prepared for the Department of Interior  
National Park Service Inventory & Monitoring Program  
In response to MOA-2007-054  
Jeffrey Cross, Program Manager  
Rebecca Beavers, MOA Specialist**

**by**

**Dan Dorfman, Marine Planner & Tim Battista, Oceanographer  
NOAA/NOS/NCCOS  
Center for Coastal Monitoring and Assessment, Biogeography Branch**

**March 15, 2012**



**A Cooperative Investigation by NOS Center for Coastal Monitoring and Assessment  
Biogeography Branch and the National Park Service, Ocean and Coastal Resources Branch**

# Gap Analysis of Marine Ecosystem Data

## TABLE OF CONTENTS

	<u>page</u>
Executive Summary .....	2
Goals .....	2
Objectives .....	2
Background .....	3
Methods.....	3
Deliverables .....	5
Results.....	6
Salt River .....	7
Buck Island .....	9
St. John Parks.....	10
Kalaupapa .....	12
Kaloko-Honokohau.....	14
War in the Pacific.....	15
National Park of American Samoa .....	17
Gap Analysis.....	18
GIS Capacity .....	21
Discussion .....	21
Gaps Identified by Park Service .....	21

## **EXECUTIVE SUMMARY**

The Gap Analysis of Marine Ecosystem Data project is a review of available geospatial data which can assist in marine natural resource management for eight park units. The project includes the collection of geospatial information and its incorporation in a single consistent geodatabase format. The project also includes a mapping portal that is available at: [http://ccma.nos.noaa.gov/explorer/gapanalysis/gap\\_analysis.html](http://ccma.nos.noaa.gov/explorer/gapanalysis/gap_analysis.html). In addition to collecting geospatial information and mapping portal, NOAA conducted a gap analysis of a standard suite of available information for managing marine resources. Additional gaps were identified by interviewing National Park Service staffs.

## **GOALS**

Through the implementation of a multi-year Interagency Agreement, the National Oceanic and Atmospheric Administration's (NOAA) Biogeography Branch (BB), provided information collection, integration, synthesis, and evaluation services for the Department of Interior (DOI), National Park Service (NPS), Inventory and Monitoring Program (I&M). The focus of partnership activities was to identify, obtain, synthesize, and evaluate all relevant ecological, oceanographic, socio-economic, cultural, and remote sensing datasets for several NPS-managed Pacific and Caribbean marine park units.

The NOAA Biogeography Branch collected and integrated available geospatial datasets to support NPS management of marine resources. The Biogeography Branch also conducted a gap analysis of spatial information resources, indicating gaps in available data. The work is an expansion of ongoing mapping and monitoring efforts conducted by NOAA and NPS in the Caribbean and Pacific using standardized protocols that enable the condition of the coral reef ecosystems within National Parks to be evaluated at local, regional, and national scales. The products from this effort provide an accurate, contemporary assessment of the abundance and distribution of biological, physical, and socioeconomic information within parks to support more effective management and conservation of ocean resources within the National Park System. The Biogeography Branch identified information gaps using a consistent gap analysis framework and interviews with NPS park staffs.

## **OBJECTIVES**

1. Identify and synthesize biological, physical, and socioeconomic data sets which are available in a spatial format and relevant to marine resource management for each park unit. Organize the data into a common GIS geodatabase framework.
2. Produce a web-based mapping and database portal to provide access to the data and metadata with security access enabled.
3. Identify additional data needs to support monitoring and management – information gaps.

## BACKGROUND

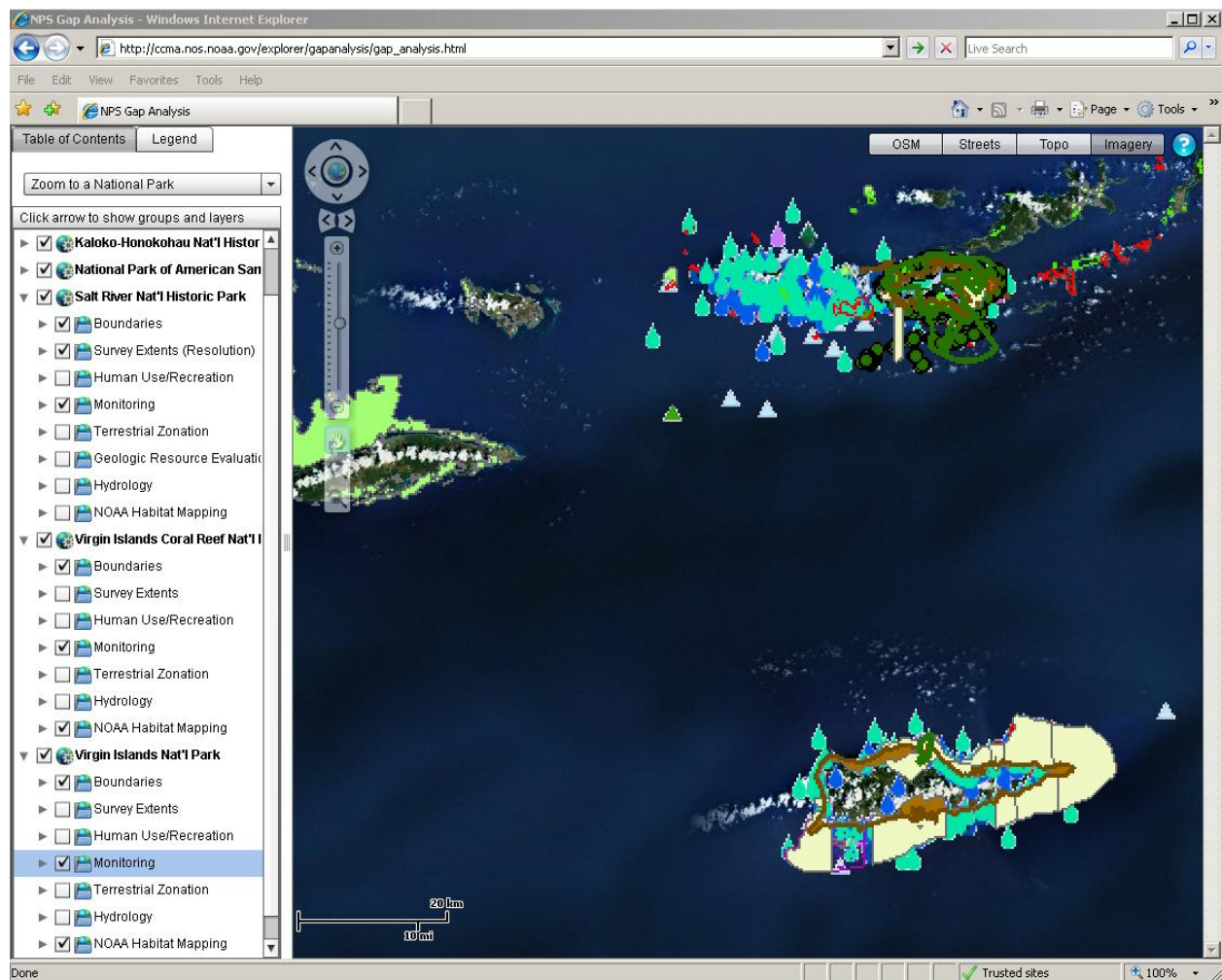
In response to President Bush's U.S. Ocean Action Plan, the National Park Service developed an Ocean Park Stewardship Action Plan to focus organizational and scientific capacity on conserving marine, estuarine, and Great Lakes resources. The Ocean Park Stewardship Action Plan strives to prevent the loss of productive fisheries, habitats, and wildlife, and continue to conserve ocean resources and recreational activities they afford to park visitors. The National Park Service manages and protects more than 250,000 acres of coral reef in eight National Park units. These include USVI - Virgin Islands National Park (VIIS), Virgin Islands Coral Reef National Monument (VICR), Salt River Bay National Historical Park and Ecological Preserve (SARI) and Buck Island Reef National Monument (BUI); Guam - War-in-the Pacific National Historical Park (WAPA); American Samoa - National Park of American Samoa (NPSA); and Main Hawaiian Islands - Kalaupapa National Historical Park (KALA) and Kaloko-Honokohau National Historical Park (KAHO).

Implementation of successful management and monitoring strategies for National Park Service Caribbean and Pacific park units is predicated on having an inventory of past and present datasets and information. While a host of academic, Federal, State, non-governmental organizations, and Territorial entities have collected information for various park units, this information is disparate in its temporal, spatial, and quantitative coverage. Developing a systematic and synoptic inventory and monitoring program requires understanding of baseline mapping and databases available to strategically target and fill existing information gaps. Furthermore, these efforts will catalyze the ability to develop standardized data collection and sampling for future investment according to place-based management priorities. NOAA's Biogeography Branch has been working in partnership with the NPS over the last 10 years to provide critical information that can support marine resource management for the parks. For more information on Biogeography Branch and NPS partnership project, see the Biogeography Branch website (<http://ccma.nos.noaa.gov/about/biogeography>).

As part of the ocean stewardship effort, the Ocean Park Stewardship Action Plan strives to improve scientific capacity to better understand ocean ecosystems and human influence. This includes providing improved products and information resources to better inform resource managers of current resource inventories and benthic habitat distribution so they can evaluate the efficacies of marine management decisions, increase scientific understanding of coral reef processes, evaluate the impact of human-uses, and monitor changing ocean conditions.

## METHODS

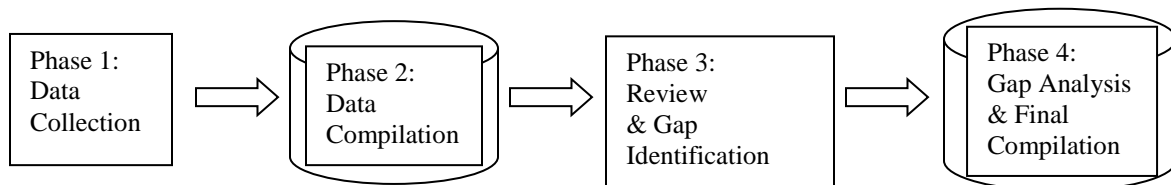
The project was conducted in four phases. The initial phase included visits to each park to meet with National Park Service staff and partners, including representatives from each of the NPS Inventory and Monitoring networks. This initial phase included collections of available data from National Park Service staff and key partners. The second phase consisted of developing a single geodatabase encompassing each park unit and a geospatial web portal ([http://ccma.nos.noaa.gov/explorer/gapanalysis/gap\\_analysis.html](http://ccma.nos.noaa.gov/explorer/gapanalysis/gap_analysis.html)) (Figure 1). The third phase consisted of reviews of the information resources and web pages, as well as interviews to identify information gaps. The fourth phase consisted of updating the geospatial portal and geodatabases with information from reviews and the gap analysis.



**Figure 1:** Example of the geospatial web portal.

Phase one began with travel to Miami on October 25, 2009 where the contractor Dan Dorfman met with staff at the South Florida and Caribbean Regional Inventory and Monitoring Network Office (Matt Paterson and team). This was followed by meetings in St Croix and St John with National Park Service Staff (Ian Lundgren, Zandy Hillis-Starr, Rafe Boulon and Christy McManus), The Nature Conservancy, Virgin Islands Department of Natural Resources, the University of the Virgin Islands, and the Virgin Islands Coastal Zone Management Program. A second site visit took place in January/February 2010, with Dorfman conducting meetings with the Pacific Island Network Regional Inventory and Monitoring Program (Kelly Kozar), National Park Service staff from Kaloko-Honokohau (Sallie Beavers) and Kalaupapa (Eric Brown), the Hawai'i Biodiversity Mapping Program, and regional Park Service staff (Sandy Margritter). This was followed by meetings in American Samoa with Park Service staff from American Samoa National Park (Paul Brown and Sarah Bone), the Coral Reef Advisory Group Coordinator at the American Samoa Department of Commerce, and the Coastal Zone Management Program. The third set of meetings associated with phase one took place in October 2010. This included meetings in Guam with Park Service staff at War in the Pacific National Park (Barbara Alberti), the US Navy, the Guam Coastal Zone Management Program, the US Fish and Wildlife Service, NOAA, and the University of Guam.

In phase two the information collected during phase one was integrated into a set of spatial databases (ESRI's file geodatabases), creating a single geographic information package for each park. This involved considerable conversion of spatial datasets to create a consistent spatial reference and to insure a coherent and complete information resource. This phase also included tracking down information which was identified by NPS staff, partners, and Biogeography Branch. Significant spatial data was contributed from regional archives of the Coral Reef Conservation Program USVI Science Coordinator (Dr. Simon Pittman). A standardized organizational scheme within the geodatabases allowed for a more objective identification of gaps in each unit's data package. The Biogeography Branch elected to serve the spatial data from these file geodatabases via a geoportal – or web mapping application – where all the information collected for each park can be reviewed by any users with an internet connection. Sam Tormey and Ken Buja led the development of the geodatabases and the web portal respectively.



**Figure 2:** A project flow chart showing the project in four phases; data collection, data compilation, review and gap analysis, and final compilation.

The third phase of the project consisted of a second round of meetings with Park Service staff to review the information resources and identify gaps in information. Meetings for the Virgin Islands parks took place in December 2010, and included review by the Park Service staff from Salt River, Buck Islands (Ian Lundgren), Virgin Islands National Park and Virgin Islands Coral Reef National Monument (Christy McManus), as well as the Nature Conservancy, and the Coastal Zone Management Program. For Pacific Islands Regional parks, review meetings took place in April 2011, and August 2011. The meetings included Park Service staffs from Kaloko-Honokohau (Sallie Beavers), National Park of American Samoa (Paul Brown and Sarah Bone), Kalaupapa (Eric Brown), and War in the Pacific (Mike Gawel) park units as well as selected partners.

The fourth and final phase consisted of gap analysis, final information compilation, and report writing. Gap analysis was conducted on a consistent suite of geospatial data recommended for each park. Additional gaps were identified through interviews with Park Service staffs.

## DELIVERABLES

Seven geodatabases were developed to cover the eight park units included in this project. VIIS and VICR were combined into a single database because the parks are adjacent to each other. Raster information is not included in the geodatabases. Instead, it is provided in a separate set of directories matching the geodatabase names. Metadata has been provided where it was available. However, many of the layers not produced by NOAA do not have metadata, and it was beyond the scope of this project to derive metadata from secondary sources. Metadata have either been linked to the geographic files or is included in a separate directory entitled Additional Metadata.



In addition to the geodatabases of spatial information, map files have been created to display the information provided in each database. The map files allow for the incorporation of vector and raster data and for the application of symbology to assist with data interpretation.

A website mapping portal (Biomapper) was created to allow access to the information for non-GIS users and to allow for a convenient way to access the spatial information. This portal is available at: [http://ccma.nos.noaa.gov/explorer/gapanalysis/gap\\_analysis.html](http://ccma.nos.noaa.gov/explorer/gapanalysis/gap_analysis.html).

The final component of the project is this report, providing a gap analysis of geospatial information available for each park.

For the purposes of this project, we define a “complete” set of data to include:

- Park Boundary
- Shoreline
- Bathymetry
- Imagery
- Socioeconomic Data (ESI)
- Water Quality Monitoring
- Fish Monitoring
- Macro Invertebrate Monitoring
- Coral Monitoring
- Shoreline Characterization (ESI)
- Impervious Surfaces (CCAP)
- Landcover
- Hydrology
- Benthic Habitat Mapping (NOAA BB)
- Digital Elevation Model

Additional layers have been provided where available (e.g., wetlands, watersheds, DEMs, and contours). These layers are included when they were found while searching for the standard suite of data.

The data compiled for this project will assist the National Park Service in advancing and maintaining GIS information resources for managing the marine environment. It is expected that the Water Resources Division will adopt the GIS resources and maintain the geoportal.

## **RESULTS**

All park units included in this project receive GIS support through the regional offices of the Inventory and Monitoring Program. However, only the St John parks (Virgin Islands National Park and Coral Reef National Monument) have the support of a full time data manager/GIS specialist. The other park units rely on either part time efforts from staff or limited support from interns or external researchers.

Some data are available for all parks. These include the benthic habitat maps developed by NOAA's Biogeography Branch (BB), land-cover and impervious surfaces developed by NOAA's Coastal Change Analysis Program, and the Environmental Sensitivity Index developed by the NOAA's Office of Response and Restoration. Beyond these consistencies, GIS resources are highly variable for each park.

### **Salt River Bay National Historical Park and Ecological Preserve (SARI)**

Salt River Bay is located along the north/central coast of St. Croix, United States Virgin Islands. Created in 1992, SARI was established to preserve, protect, and interpret nationally significant natural, historical, and cultural resources for the benefit of present and future generations (United States Congress 1992). The park's roughly 1,015 acres encompass marine, estuarine, and terrestrial habitats, including the largest remaining mangrove forest within the U.S. Virgin Islands, coral reefs, seagrass beds, and a submarine canyon (from park website).

#### **GIS Resources Available:**

##### **Boundaries:**

- Park Boundary (NPS)
- Shoreline (NOAA)
- Coastal Zone planning areas (CZM)
- Areas of Particular Concern (CZM)

##### **Human Use:**

- Socioeconomic Data (NOAA-ESI)
- Roads

##### **Water Quality Monitoring:**

- St Croix Ambient Monitoring Locations (DPNR EP)
- DPNR Virgin Islands Water Quality Monitoring Stations (DPNR EP)
- Northeast St Croix Water Quality Monitoring Stations (DPNR EP)
- EPA Water Quality Monitoring Stations (1999-2009) (EPA)
- EPA Water Quality Monitoring Stations (1988-1999) (EPA)
- EPA Water Quality Assessment Units (EPA)

##### **Coral Monitoring:**

- Florida Fish and Wildlife Acropora Presence/Absence (FFWC)
- Stony Coral Biocriteria Assessment Study Locations (EPA)
- Territorial Coral Reef Monitoring Program (TCRMP) Stations (DPNR and UVI)
- Coral Reef Early Warning System Stations (NOAA)

##### **Fish Monitoring**

- Reef Fish Census Stations (UVI-CMES)



## Monitoring

- Mangrove Restoration Sites (NPS)
- Water Temperature Monitoring Stations (UVI-CMES)
- Sediment Monitoring Stations (UVI-CMES)

## Terrestrial Zonation:

- Shoreline Classification (NOAA-ESI)
- St Croix Impervious Surfaces (NOAA-CSC)
- St Croix Vegetation (UVI CDC)
- St Croix Land Use/Land Cover (NOAA CCAP)
- St Croix Soil
- Fugro LADS LIDAR DEM 2011 (NOAA)
- St Croix Digital Elevation Model 30 m (USGS)

## Geologic Resource Evaluation:

- St Croix Geologic Altitude and Observation Points
- St Croix Fault and Fold Map Symbolology
- St Croix Folds
- St Croix Faults
- St Croix Geologic Contacts
- St Croix Geologic Units

## Hydrology:

- St Croix Rivers
- St Croix Wetlands
- St Croix Watersheds

## Bathymetric Survey Extents

- Nancy Foster Cruise 2005 (NOAA)
- Nancy Foster Cruise 2006 (NOAA)
- Fugro LADS LIDAR bathymetry 2011 (NOAA)
- Orthophotos 2007 (USACE)
- IKONOS 2007 (NOAA)

## NOAA Habitat Mapping:

- Accuracy Assessment Sites (NOAA)
- Seagrass and Mangrove Habitat Extent 2000 (NOAA BB)
- Seagrass and Mangrove Habitat Extent 1992 (NOAA BB)
- Seagrass and Mangrove Habitat Extent 1988 (NOAA BB)
- Seagrass and Mangrove Habitat Extent 1970s (NOAA BB)
- Salt River Benthic Habitats 2000 (NOAA BB)
- St Croix Benthic Zones 1999 (NOAA BB)
- St Croix Benthic Habitats 1999 (NOAA BB)

## **Buck Island Reef National Monument (BUIS)**

Buck Island Reef National Monument was established to preserve "one of the finest marine gardens in the Caribbean Sea." The park is one of a few fully protected marine areas in the National Park System. The 176-ac island and surrounding coral reef ecosystem support a variety of native flora and fauna, including the hawksbill turtle and brown pelican (from park website).

### **GIS Resources Available:**

#### **Boundaries:**

- Park Boundary (NPS)
- Buck Island Shoreline (NOAA)
- St Croix Shoreline (NOAA)
- Coastal Zone Tier 1 planning areas (CZM)
- Areas of Particular Concern (CZM)

#### **Human Use/Recreation:**

- Socioeconomic Data (NOAA-ESI)
- Roads
- Buck Island hiking trail (NPS)
- Buoys in Buck Island vicinity, 2007 (NPS)
- Buck Island buildings

#### **Water Quality Monitoring:**

- St Croix Ambient Monitoring Locations (DPNR EP)
- Buck Island Water Temperature Monitoring Stations (NPS)
- Virgin Islands Water Quality Monitoring Stations (DPNR EP)
- Northeast St Croix Water Quality Monitoring Stations
- Water Quality Monitoring Stations (1999-2009) (EPA)
- Water Quality Monitoring Stations (1988-1999) (EPA)
- Water Quality Assessment Units (EPA)

#### **Coral Monitoring:**

- Florida Fish and Wildlife Acropora Presence/Absence
- Stony Coral Biocriteria Assessment Study Locations (EPA)
- Territorial Coral Reef Monitoring Program Stations (TCRMP) (DPNR and UVI)
- Locations of Elkhorn Coral Colonies Identified in Pilot Study (TNC/CDC)
- NPS – SFCN Coral Monitoring – Western Spur and Groove
- NPS – SFCN Coral Monitoring – South Forereef

#### **Fish and Invertebrate Monitoring:**

- Spiny Lobster Assessment Locations (2004-present) (FFWC and NPS)
- Queen Conch Stock Assessment Locations (2001) (DPNR)
- Reef Fish Census Stations (DPNR and UVI)

#### Monitoring – NOAA Caribbean Coral Reef Ecosystem Monitoring Project

- Dive Locations for monitoring fish, corals, conch, lobster, *Diadema*, and *Acropora* (2001-2010) (NOAA BB)
- UVI Benthic Habitat Monitoring Stations

#### Terrestrial Zonation:

- Shoreline Classification (NOAA ESI)
- St Croix Impervious Surfaces (NOAA CCAP)
- St Croix Land Use/Land Cover (NOAA CCAP)
- St Croix Vegetation (UVI CDC)
- St Croix Soil
- St Croix Digital Elevation Model 30 m (USGS)

#### Geologic Resource Evaluation:

- St Croix Geologic Attitude and Observation Points
- St Croix Fault and Fold Map Symbology
- St Croix Folds
- St Croix Faults
- St Croix Geologic Contacts
- St Croix Geologic Units

#### Hydrology:

- St Croix Rivers
- St Croix Wetlands
- St Croix Watersheds

#### Bathymetric Survey Extents:

- R/V Osprey 2010, 1 m resolution (NPS)
- R/V Nancy Foster 2006, 10 m resolution (NOAA)
- R/V Ronald Brown 2006, 50 m resolution (USGS)
- R/V Nancy Foster 2005, 1 m resolution (NOAA)
- R/V Nancy Foster 2004, 5 m resolution (NOAA)
- Fugro LADS LIDAR 2011 3 m resolution (NOAA)

#### NOAA Habitat Mapping:

- Benthic Habitats Buck Island Area 2001 (NOAA BB)
- Benthic Zones St Croix 1999 (NOAA BB)
- Benthic Habitats St Croix 1999 (NOAA BB)

#### **St. John Parks: Virgin Islands Coral Reef National Monument (VICR) and Virgin Islands National Park (VIIS)**

Virgin Islands Coral Reef National Monument includes federal submerged lands within the 3 mile belt off of the island of St. John. These waters support a diverse and complex system of coral reefs, and other ecosystems such as shoreline mangrove forests and seagrass beds that

contribute to their health and survival. In 1962, Congress expanded the boundary of Virgin Islands National Park to include 5,650 ac of submerged lands to protect and preserve the beautiful coral gardens and seascapes. Today, the park conducts research and has developed policies and practices aimed at protecting the fragile coral reef systems (from park website).

#### GIS Resources Available:

##### Boundaries:

- Park Boundary Virgin Islands National Park (NPS)
- Park Boundary Virgin Islands Coral Reef National Monument (NPS)
- St John Shoreline
- St John Areas of Particular Concern (CZM)
- St John Coastal Zone Tier 1 (CZM)
- Management (NOAA-ESI)

##### Human Use/Recreation:

- Socioeconomic Data (NOAA-ESI)
- Roads
- Aids to Navigation
- National Park Seagrass Moorings
- Tourism Zones (TNC)
- Ferry Route

##### Water Quality Monitoring:

- Water Quality Monitoring (DPNR)
- Water Quality Monitoring (NPS)
- Water Quality Monitoring (EPA/STORET)
- Water Quality Monitoring after 1999 (EPA)
- Water Quality Monitoring before 1988-1999 (EPA)

##### Coral Monitoring:

- Acropora (USGS and BB)
- Acropora Presence/Absence (Florida Fish and Wildlife)
- Acropora Stations (NOAA-NMFS)
- Acropora Census Stations (UVI-CMES)
- Lameshur Bay Long Term Coral Monitoring Stations (CSUN)
- Territorial Coral Reef Monitoring Stations (TCRMP)
- Coral Monitoring Stations (NPS-SFCN)

##### Fish and Invertebrate Monitoring:

- Fish Acoustic Tracking Stations (NOAA and UVI)
- Queen Conch Hydrophone Tracking Study Locations (NOAA-NMFS)
- Queen Conch Stock Assessment Locations 2001

#### Monitoring:

- Caribbean Coral Reef Ecosystem Monitoring Project: Dive Locations for monitoring fish, corals, conch, lobster, *Diadema*, and *Acropora* 2001-2010 (NOAA)
- Seagrass Extents (TNC)

#### Terrestrial Zonation:

- Shoreline Characterization (NOAA-ESI)
- St John Impervious Surfaces (NOAA-CCAP)
- St John Digital Elevation Model 30 m (USGS)

#### Hydrology:

- St. John Rivers
- St. John Wetlands
- St. John Watersheds

#### Bathymetric Survey Extents:

- Nancy Foster 2011, 1 m resolution (NOAA)
- Nancy Foster 2010 1 m (NOAA)
- Nancy Foster 2005 2 m (NOAA)
- Nancy Foster 2004 5 m (NOAA)
- IKONOS Satellite Imagery 2005
- Orthophotography (Army Corps of Engineers)
- Fugro LADS LIDAR 2011 3 m resolution (NOAA)

#### NOAA Habitat Mapping:

##### Shallow Water Mapping:

- Geographic Zone (NOAA BB)
- Biological Cover (NOAA BB)
- Geomorphological Structure (NOAA BB)
- Ground Validation and Accuracy Assessment Points (NOAA BB)

##### Moderate Depth Mapping 2009:

- Geographic Zone (NOAA BB)
- Biological Cover (NOAA BB)
- Geomorphological Structure (NOAA BB)
- Ground Validation and Accuracy Assessment Points (NOAA BB)
- Ground Validation and Accuracy Assessment Transects (NOAA BB)

#### **Kalaupapa National Historical Park (KALA), Molokai, Hawai'i**

This park is complicated to manage since the lands, waters, and historic buildings are not owned by the National Park Service. Spectacular north shore sea cliffs, narrow lush valleys, a conic volcanic crater, verdant rain forest, lava tubes and caves, offshore islands and coral reefs all exist within the national park boundary. Several of these areas provide rare native habitat for threatened or endangered Hawaiian plants and animals. Hawaiian Monk seal pups have been

born on Kalaupapa beaches. These endangered mammals require solitude; Kalaupapa's physical isolation provides perfect habitat to support their births and subsequent care (from park website).

#### GIS Resources Available:

##### Boundaries:

- Kalaupapa Park Boundary (NPS)
- Molokai Shoreline

##### HumanUse/Recreation:

- Landfills
- Helicopter Landing Sites
- Molokai Roads and Trails
- Kalaupapa Fences (NPS)
- Kalaupapa Buildings (NPS)

##### Coral Monitoring:

- Coral Settlement Abundance and Composition
- Benthic Habitat Sampling Coral Cover (NPS)

##### Fish and Invertebrate Monitoring:

- Fish Abundance by Trophic Level (NPS)
- Fish Biomass by Trophic Level (NPS)
- Other Fish Metrics by Year (NPS)
- Invertebrate Survey Locations (SWCA, 2006)
- Invertebrate Survey Locations (NPS, 2002-2005)

##### Monitoring

- Kalaupapa Algae Survey Locations (NPS)
- Tidepool Locations
- Intertidal Zone
- Temporary Sampling Transects (NPS, 2008)
- Benthic Habitat Sampling Transects (NPS, 2007)
- Benthic Habitat Sampling Transects (NPS, 2006)
- Fixed Sampling Transects Comparison (NPS, 2006-2007)
- Benthic Habitat Sampling Transects (SWCA, 2004-2007)
- Rugosity transect Start Points (NPS, 2006-2010)
- Wave Energy Zones (NPS)
- Bottom Type Classification 10–20 m depth (NPS, 2008)
- Monk Seal Survey Sites (2005-present)
- Shoreline Bird Inventory (2005)

##### Terrestrial Zonation:

- Molokai Impervious Surfaces (NOAA CCAP)
- Molokai Land Use/Land Cover (NOAA CCAP)

- Molokai Landcover (HIGAP)
- Digital Elevation Model 10 m (USGS)
- Terrestrial Contours

#### Hydrology:

- Stream Gauges
- Waterfalls
- Aquifers

#### NOAA Habitat Mapping (2007):

- Benthic Habitat Ground Validation Sites (NOAA BB)
- Benthic Zones (NOAA BB)
- Benthic Biological Cover (NOAA BB)
- Benthic Geomorphological Structure (NOAA BB)

### **Kaloko-Honokohau National Historical Park (KAHO), Hawai'i**

Extensive lava fields meet the sea along the Kona coastline on the Island of Hawai'i. This dry and barren region provided the vital sustenance for the people who once lived here, with abundant fishing and access to fresh water from brackish pools. A close relationship with nature created a strong connection with the wind, the sea and the landscape. The Hawaiian green sea turtle (*honu*) frequents the shoreline of the park and often basks in the warm Hawaiian sun (from park website).

#### GIS Resources Available:

##### Boundaries:

- Kaloko-Honokohau National Historic Park Boundary (NPS)
- Fishery Management Areas
- Land Stewardship (HI-GAP)
- Marine Managed Areas (HI-GAP)
- Reserves (HI-DBEDT-2008)
- Hawaii Shoreline (NOAA)
- State Waters 3 nm

##### Human Use/Recreation:

- Aids to Navigation
- Dive Sites (HBMP)
- Boating Facilities
- Fish Ponds
- Harbor
- Socioeconomic Data (NOAA-ESI)
- Roads
- Sewer Lines



Coral Monitoring:

- Precious Coral (NOAA-ESI)
- Coral Reef Areas (NOAA)

Fish and Invertebrate Monitoring:

- Nearshore Fish and Invertebrate Priority Areas (TNC)

Monitoring:

- Spinner Dolphins (TNC)
- Hawksbill Turtle Foraging (TNC)

Terrestrial Zonation:

- Impervious Surfaces (NOAA-CCAP)
- Geologic Map (USGS)
- Land Cover (NOAA-CCAP)
- Shoreline Classification (NOAA-ESI)
- Hawaii Digital Elevation Model 10 m (USGS)

Hydrology:

- Anchialine Pools
- Wetlands (NOAA-ESI)
- Fish Ponds

NOAA Habitat Mapping:

- Benthic Habitats 2007 (NOAA BB)
- Benthic Ground Validation 2007 (NOAA BB)
- Benthic Accuracy Assessment 2007 (NOAA BB)
- Benthic Habitats 2000 (NOAA BB)

**War in the Pacific National Historical Park (WAPA), Guam**

At War in the Pacific National Historical Park the former battlefields, gun emplacements, trenches, and historic structures all serve as silent reminders of the bloody World War II battles that ensued on Guam. While the park is known for its historical resources, the warm climate, sandy beaches, and turquoise waters beckon visitors and residents to enjoy the island's natural resources. Over 3,500 marine species and 200 species of coral are located within scuba and snorkeling areas of park waters. The park is dedicated to long-term monitoring of Guam's coral reefs and is committed to completing comprehensive inventories of the flora and fauna (from park website).

GIS Resources Available:

Boundaries:

- War in the Pacific Park Boundary
- Marine Protected Areas

- Guam Shoreline (NOAA)

#### Human Use/Recreation:

- Socioeconomic Data (NOAA-ESI)
- Major Roads

#### Coral Monitoring:

- Rapid Ecological Assessment Locations (NOAA-CRED, 2003-2011)
- Towed-Diver Surveys (NOAA-CRED, 2003-2011)

#### Fish Monitoring:

- Rapid Ecological Assessment Locations (NOAA-CRED, 2003-2011)
- Towed-Diver Surveys (NOAA-CRED, 2003-2011)

#### Terrestrial Zonation:

- Shoreline Classification (NOAA-ESI)
- Impervious Surfaces (NOAA-CCAP)
- Vegetation (PIVM)
- Land Cover (NOAA-CCAP)
- Molokai Digital Elevation Model 10 m (USGS)

#### Geological Resource Evaluation:

- Geologic Attitude and Observation Localities
- Sample Locations
- Mines
- Folds
- Faults
- Linear Dikes
- Contacts
- Linear Joints
- Cross Section Lines
- Geologic Units

#### Hydrology:

- Rivers and Streams (USGS)
- Wetlands (NOAA-ESI)
- Watersheds (University of Guam)

#### Bathymetric Surveys:

- Apra Harbor 1 m (NOAA/Navy 2008),
- Guam 5 m (NOAA)
- Guam 60 m (NOAA)

#### NOAA Habitat Mapping:

- Benthic Habitat Class (NOAA BB)

- Biological Cover (NOAA BB)
- Geomorphological Structure (NOAA BB)

### **National Park of American Samoa (NPSA), American Samoa**

Located in the Southwest Pacific Ocean, the national park occupies three volcanic and mountainous islands clothed in tropical rainforest, ringed with rugged cliffs, glistening beaches, and coral reefs. The national park preserves and protects tropical rainforests, coral reefs, fruit bats, and the Samoan culture (from park website).

GIS Resources Available:

Boundaries:

- Park Boundary National Park of American Samoa (NPS)
- Coastline (NOAA)
- Community Based Fishery Management
- Coastal Zone Management Program Boundary
- Other Marine Reserves
- Quickbird Imagery 2005 (0.6 m)

Human Use/Recreation:

- Socioeconomic Data (ESI-NOAA)
- Trails (NPS)
- Roads (ASDOC)

Water Quality Monitoring:

- Quarterly Water Quality Monitoring Sites (ASEPA)
- Weekly Water Quality Monitoring Sites (ASEPA)

Coral Monitoring:

- Rapid Ecological Assessment Locations (CRED, 2002-2010)
- Towed-Diver Transects (CRED, 2002-2010)

Fish Monitoring:

- Rapid Ecological Assessment Locations (CRED, 2002-2010)
- Towed-Diver Transects (CRED, 2002-2010)

Monitoring:

- Fruit Bat Distribution (NPS)
- Petrel Nesting Sites (NPS)
- Legacy Bird Stations (USFWS)

Terrestrial Zonation:

- Shoreline Classification (ESI-NOAA)
- Vegetation (USFS 2004)

- Soil Type (USDA)
- 10 m Topographic Contours (USGS)
- American Samoa Digital Elevation Model 10 m (USGS)

#### Hydrology:

- Manu'a Island Rivers (USGS)
- Tutuila Rivers (ASEPA)
- American Samoa Wetlands (ASEPA)
- Tutuila Subwatersheds (ASEPA)
- American Samoa Watersheds (ASEPA)

#### Bathymetric Survey Extents:

- Ofu/Olosega MBES Bathymetry (5 m) (NOAA CRED)
- Ta'u MBES Bathymetry (10 m) (NOAA CRED)
- Tutuila Derived Bathymetry (5 m) (NOAA)

#### NOAA Habitat Mapping:

- Tutuila Benthic Zone 2011 (NOAA BB)
- Tutuila Benthic Habitat Structure 2011 (NOAA BB)
- American Samoa Benthic Zones (NOAA BB)
- American Samoa Benthic Habitat Structure (NOAA BB)
- American Samoa Benthic Percent Major Cover (NOAA BB)
- Accuracy Assessment (NOAA-2002)
- Ground Validation Sites (NOAA-2002)

## **GAP ANALYSIS**

Table 1 shows existing data holdings and gaps by park for the major thematic resource themes. In general, the NOAA Biogeography Branch and the National Park Service I&M program can assist local park staff with in-water coral reef ecosystem and species monitoring, bathymetry, and habitat mapping. The USGS and EPA are primary contacts for land-based issues and water quality.

Park boundaries are included for each park. In most cases these boundaries were provided by the National Park Service. The exception to this is the park boundary for NPSA which was provided by the USGS. These coverages are not legal boundaries and are meant for display purposes only.

Shorelines are provided for each park. The shorelines were digitized from recent imagery to capture recent changes along the coast. In most cases, shorelines were derived by Biogeography Branch at a 1:24,000 scale from IKONOS imagery. The exception is BUIS, which was derived from aerial photography.

**Table 1.** Comparison of existing data holdings among parks. X = park has some data, but it may not be complete spatial and temporal coverage.

RESOURCES	SARI	BUIS	STJO	KALA	KAHO	WAPA	NPSA
Park Boundary	X	X	X	X	X	X	X
Shoreline	X	X	X	X	X	X	X
Bathymetry	X	X	X	X	X	X	X
Imagery	X	X	X	X	X	X	X
Socioeconomic Data (ESI)	X	X	X	X	X	X	X
Water Quality Monitoring	X	X	X			X	X
Fish Monitoring	X	X	X	X		X	X
Macroinvertebrate Monitoring		X	X	X			
Coral Monitoring	X	X	X	X		X	X
Shoreline Characterization (ESI)	X	X	X	X	X	X	X
Impervious Surface (CCAP)	X	X	X	X	X	X	
Landcover	X	X	X	X	X	X	X
Hydrology	X		X	X		X	X
Benthic Habitat Mapping	X	X	X	X	X	X	X
Digital Elevation Model	X	X	X	X	X	X	X

**Bathymetry:** Bathymetry has been collected for most parks. NPSA has complete coverage; Tutuila and Ofu/Olosega are mapped at 5 m scale while Tau is mapped at 10 m scale. BUIS, SARI, and VICR have nearly complete coverage. BUIS has been mapped at scales ranging from 1–1,830 m with only a small segment still missing. SARI has been mapped at scales ranging from 1–10 m depending on depth but inshore turbid areas are still lack bathymetry coverage. VICR has been mapped at scales 2 m and 5 m. WAPA has only a very small portion of its area mapped for bathymetry at a scale of 5 m. Lidar bathymetry is available for the shallower portion of KAHO covering roughly 50% of the park. Lidar bathymetry was also found for Molokai, covering roughly 60% of the park unit. Bathymetry for VIIS and VICR from multibeam and Lidar surveys is nearly complete coverage.

**Imagery:** IKONOS imagery has been provided for each park. Several of the parks had additional imagery available. Orthophotography from the Army Corps of Engineers is available for BUIS and SARI. SPOT imagery is provided for KAHO. KALA has SPOT, IKONOS and Quickbird imagery available. NPSA has IKONOS and Quickbird imagery. VIIS and VICR have IKONOS and orthophotography.

**Socioeconomic Data:** All parks have coverage from the Environmental Sensitivity Index, including socioeconomic activities.

**Water Quality Monitoring:** Water quality monitoring is available within the park BUIS, SARI, VIIS and WAPA. Water quality monitoring information is available adjacent to VICR and NPSA. No water quality information was found for WAPA, KAHO, or KALA. Water quality

information for KAHO and KALA should be a priority as this information is likely to be relevant to management concerns in these areas.

Fish Monitoring: KALA has extensive fish monitoring conducted annually by park service staff. BUIS and St John parks have extensive fish monitoring conducted by NOAA Biogeography Branch. NPSA has extensive fish monitoring provided by NOAA CRED, which monitors once every two years. WAPA has limited fish monitoring data collected by CRED; only a small portion of the park is monitored every two years. SARI has limited coverage by the UVI-CMES reef fish census. No fish monitoring information was found for KAHO. Fish monitoring is limited to SCUBA depths (<30 m) and no deeper fish monitoring work was found.

Macroinvertebrate Monitoring: BUIS has extensive macroinvertebrate monitoring, particularly for spiny lobsters and queen conch. VIIS has macroinvertebrate monitoring, particularly for queen conch. No macroinvertebrate monitoring data were found for SARI, VICR, or KAHO. Limited coverage is available for WAPA and NPSA from CRED surveys that are conducted every two years. All macroinvertebrate monitoring was in diving depths (<30 m).

Coral Monitoring: Coral monitoring is extensive for all parks with the exceptions of KAHO and WAPA. WAPA has limited spatial coverage from CRED surveys which only cover a very small portion along the edge of the park units and KAHO is expected to have coral monitoring information which was not obtained during this project. All coral monitoring was in diving depths (<30 m). WAPA and NPSA have surveys conducted every two years.

Shoreline Characterization: All parks have a shoreline characterization from the Environmental Sensitivity Index. The Environmental Sensitivity Index has been developed by NOAA's Office of Response and Restoration to aid responders in the event of an oil spill or other disaster.

Impervious Surfaces: Impervious surfaces are available for all parks. However, the Tutuila portion of NPSA does not have impervious surface coverage. These coverages were produced by NOAA's Coastal Service Center Coastal Change Analysis Program (CCAP).

Landcover: Landcover is provided for all parks from the NOAA Coastal Change Analysis Program. Where available (SARI, NPSA, KALA, WAPA), additional landcover data are included.

Hydrology: Hydrology is included for all parks except KAHO and BUIS. These parks have minimal surface hydrology. Wetlands are included for KAHO and BUIS.

Benthic Habitat Mapping: Benthic habitats developed by Biogeography Branch are included for all parks. Biogeography Branch benthic habitat maps were derived from IKONOS imagery and extend to a depth of 30 m. The exception is in the water surrounding St John where moderate depth mapping has been conducted to 60 m.

Digital Elevation Models: Digital elevation models are included for each park. These were provided by USGS. Pacific parks are provided at a 10 m grid while Caribbean parks are provided at a 30 m grid.

## **GIS CAPACITY**

SARI does not have dedicated GIS capacity. The park is co-managed with the Virgin Islands Department of Natural Resources.

Buck Island does not have dedicated GIS staff. Some support is available through the park biologist, Ian Lundgren. Buck Island is comparatively data rich.

VIIS and VICR have a dedicated data manager/GIS specialist, Christy McManus. These are the only parks in this project that have full time data management/GIS capacity.

KALA does not have dedicated data management or GIS capacity. Instead, this park relies on part-time contributions for staff.

KAHO does not have data management or GIS support on an on-going basis. It relies on interns and external researchers to provide assistance.

WAPA has a biological technician with GIS ability who is supported by the I&M Program.

NPSA has part-time data management and GIS capacity provided by park ranger Sarah Bone.

## **DISCUSSION**

Park boundaries, shorelines, bathymetry, imagery, socioeconomic data, shoreline characterization, landcover, benthic habitat mapping and digital elevation models are available for all parks creating a standard set of geographic resources. Buck Island Reef National Monument, Virgin Islands Coral Reef National Monument, Virgin Islands National Park, Kalaupapa, and Kaloko-Honokohau have extensive coral and fish surveys that are conducted on a regular basis. For Buck Island Reef National Monument, Virgin Islands Coral Reef National Monument, and Virgin Islands National Park, surveys are conducted by NOAA's Biogeography Branch. In Hawai'i, surveys are conducted by the National Park Service. Salt River, National Park of American Samoa, and War in the Pacific do not have regular surveys of fish and corals within their boundaries. Surveys are conducted in Hawai'i, Guam, and American Samoa by NOAA's Coral Reef Ecosystem Division, but these surveys do not focus effort within park boundaries. KAHO and NPSA seem most in need of increased surveys for fish and corals.

## **GAPS IDENTIFIED BY PARK SERVICE**

In addition to the systematic gap analysis of available geospatial information for each park, we interviewed park service staffs and partners to determine priority information needs. Below is a list of information needs identified through these interviews. Gaps in areas where knowledge is lacking are indicated with an asterisk (\*).

SARI:

- Sea turtle habitat information
- Seagrass monitoring
- Need 100% bathymetry and backscatter



- Maritime archeology and marine debris (derelict fishing gear) detection
- Contaminants assessment (sediment and biota)

#### BUIS:

- Fish movements and connectivity (fish acoustics network)
- Spawning aggregation sites and larval connectivity
- Shoreline change detection
- Oceanographic characterization
- Coral monitoring - fixed stations
- Sea turtle habitat
- Sea urchin information\*
- Lobster surveys
- Conch surveys
- Coral recruitment and growth monitoring
- Chemical contaminants (sediments and biota)

#### St John Parks (VIIS and VICR):

- King's Reef monitoring
- South shore coral monitoring
- Small scale currents\*
- Coral connectivity
- Coral bioindicators
- Coral recruitment
- Upstream data, British Virgin Islands, Saba Bank
- Genetics for resilient reefs
- Coral disease tracking
- Staghorn coral information
- Information on contaminants from ships and shore
- Territorial marine protected areas

#### KALA:

- Fine scale currents\*
- Fishing pressure
- Lobster surveys
- Octopus surveys
- Opihi surveys
- Invasive species (fish and algae)
- Endangered species
- Water quality information

#### KAHO:

- Oceanographic characterization
- Upstream impacts, erosion and sedimentation
- Ground water impacts from upstream development

WAPA:

- Benthic habitat of offshore banks
- Larval sources and sinks
- Shallow reef surveys beyond the 10-20m contours
- Unexploded ordinance
- Higher resolution habitat maps
- Fishing pressure in the park
- Stormwater runoff effects on corals (sediment studies)
- Coral recruitment
- Turtles
- Expand coral and fish surveys in park
- Projected uses during and after build-up
- Surveys for proposed/listed endangered species
- Historical records of storms and flooding\*
- Wildfires\*
- Currents/larval settlement\*
- Temperature (local scale variation)\*
- Climate change impacts (bleaching areas)\*
- Recreational dive pressure and impacts\*
- Invasive species (crown of thorns starfish)\*
- Marine invertebrate surveys (sea cucumbers)\*

NPSA:

- Seabird nesting
- Turtle nesting beaches
- Water quality profiles\*
- Fine scale currents\*
- Fish movements
- Higher resolution coral cover within the park
- Ofu back reef mapping higher resolution
- Invasive species distributions
- Archeological sites\*
- Spatially-referenced photos
- GIS data organization/compilation
- Weather stations\*